Original Article

Measurement of Aortic Root Dimensions by Transesophageal Echocardiography in Adult Patients Undergoing Cardiac Surgery

Abstract

Background: Normal aortic root dimensions were established from studies from Western countries. As the body size is significantly associated with the aortic root dimensions, Thai populations may have smaller aortic root diameters. **Aims:** To elucidate the aortic root dimensions using transesophageal echocardiography (TEE) in adult patients undergoing cardiac surgery. **Settings and Design:** A retrospective cohort study including 150 patients aged >18 years undergoing cardiac surgery. **Materials and Methods:** Aortic root dimensions (annulus, sinus of Valsalva, sinotubular junction (STJ), and proximal ascending aorta) were measured using two-dimensional TEE. Patients with aortic-root related pathology were excluded. **Results:** Men constituted 60% of the study population; the mean age was 61.9 ± 12.6 years, and mean body surface area (BSA) was 1.7 ± 0.2 m^2. The absolute dimensions for the annulus, sinus of Valsalva, STJ, and proximal ascending aorta were 22.3 ± 3.4, 32.6 ± 3.9, 26.4 ± 3.3, and 29.3 ± 3.1 mm, respectively, in men (12.9 ± 1.6, 18.8 ± 2.6, 15.2 ± 2.1, and 17.9 ± 2.7 mm, respectively, after adjusting for BSA) and 20.3 ± 2.2, 29.8 ± 3.6, 23.8 ± 2.6, and 27.1 ± 3.1 mm, respectively, in women (13.5 ± 2.0, 19.8 ± 2.3, 15.8 ± 2.5, and 17.0 ± 2.1 mm, respectively, after adjusting for BSA). The absolute aortic root diameters were significantly greater in men at all levels ($P < 0.001$). The BSA-adjusted diameters were similar for both sexes at the annulus ($P = 0.076$) and STJ ($P = 0.076$), except for the sinus of Valsalva ($P = 0.010$) and proximal ascending aorta ($P = 0.006$). **Conclusion:** This study reports reference values of aortic root dimensions by TEE. The body size should be considered when comparing the aortic root dimensions of Thai populations with the standard normal values.

Keywords: *Adult, aorta, echocardiography, reference values, transesophageal*

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Introduction

The aortic root dimensions are crucial for determining the appropriate timing for prophylactic aortic surgery because aortic root dilatation is associated with increased morbidity and mortality due to aortic dissection.[1] The aortic root dimensions are routinely evaluated during comprehensive echocardiographic examination. Transthoracic echocardiography (TTE) is a preferred method to evaluate the aortic root size due to its feasibility and patient's comfort. Several previous studies have reported the normal values of the aortic root dimensions using TTE in either the M-mode or by performing two-dimensional echocardiography.[2-6] However, transesophageal echocardiography (TEE) is more advantageous than TTE, and it is recommended as one of the reliable tools to assess the aortic root dimensions.[7] TEE allows better visualization of aortic structures compared with TTE. The high-resolution image can be obtained with TEE due to the proximity of the aorta and the TEE probe. Further, multiplane imaging from TEE allows better assessment of the aortic root. However, TEE is more invasive and is rarely performed in patients without cardiac pathology.

The majority of the established normal values of the aortic root dimensions were derived from studies from Western countries.[1-4] As body size is consistently documented as one of the primary determinants of the aortic root dimensions,[2-4,8] Thai populations are expected to have smaller aortic root dimensions compared to the Caucasian populations. Even though there have been a few published literature on aortic root size in Asian populations,[6,9] the association with the body size was not clearly demonstrated in those studies. We hypothesize that the reference values of the aortic root dimensions for Thai populations may be

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smaller than the current standard normal values. Since TEE allows better assessment of the aortic root and it is routinely performed for patients undergoing cardiac surgery at our institution, we aimed to evaluate a full spectrum of aortic root dimensions using TEE in adult patients undergoing cardiac surgery.

Materials and Methods

This retrospective cohort study was approved by the institutional review board (Ref. Si 775/2016) with the exemption of consent. The study included 150 patients, aged 18 years and older, who had undergone cardiac surgery with intraoperative TEE examination from October 2016 to December 2017. The patients who were diagnosed with aortic valve or left ventricular outflow tract pathology, aortic disease, or connective tissue disease were excluded. The TEE images of inadequate quality were not assessed. The medical records and TEE images were retrieved from the hospital electronic database. Patient characteristics, including age, height, body weight, and underlying diseases were recorded. The body surface area (BSA) was calculated using the Dubois and Dubois formula.[10] Significant valvular heart disease was defined as the pathology with moderate or severe stenosis or regurgitation.

Echocardiography

TEE was performed using iE33, Affiniti70, and Epiq7 (Philips Medical System, Netherlands). The aortic root diameters were measured in the mid-esophageal long-axis view of the aortic valve. Dimensions of the four standard sections of the aortic root, namely, the aortic annulus, sinus of Valsalva, sinotubular junction (STJ), and proximal ascending aorta (measured at 1 cm above the STJ), were measured. The aortic annulus was measured at mid-systole using the inner edge to inner edge convention, whereas the sinus of Valsalva, STJ and proximal ascending aorta were measured at the end of diastole, perpendicular to the long axis of the aorta, using the leading edge to leading-edge convention[11] as shown in Figure 1.

All TEE measurements were analyzed by two independent cardiac anesthesiologists with certified TEE training. Interobserver variability was assessed by the measurement of the aortic root dimensions of randomly selected 50 subjects.

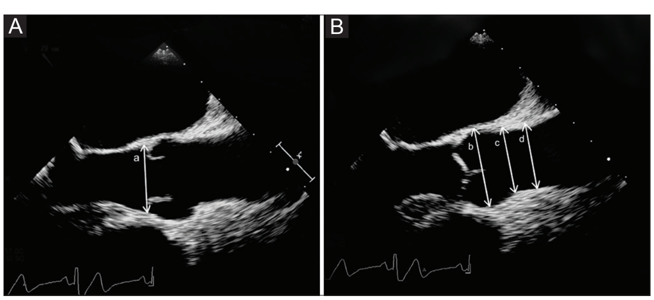

Figure 1: Measurement of aortic root dimensions by TEE. Aortic annulus (a) was measured at mid-systole (A). Sinus of Valsalva (b), STJ (c), and proximal ascending aorta (d) were measured at the end of diastole (B)

Statistical analysis

This study aimed to evaluate the aortic root dimensions using TEE in adult patients undergoing cardiac surgery. The sample size calculation was based on the standard deviation of the aortic diameter, which was approximately 3.0 mm according to the study by Vriz *et al*.,[4] with a 95% confidence interval and a margin of error of 0.5 mm. Accordingly, a sample size of at least 137 subjects was required.

The patient characteristics and demographic data were analyzed using descriptive statistics. The mean and standard deviation (mean ± SD) are reported for continuous variables with normal distribution; otherwise, the median with an interquartile range have been reported. The aortic root dimensions were presented as mean ± SD and were compared between sexes using the unpaired *t*-test. P values of less than 0.05 were considered statistically significant. The intraclass correlation coefficient (ICC) was used to evaluate the interobserver reliability; an ICC of more than 0.7 indicated high reliability. The statistical analysis was performed using SPSS version 18 (SPSS, IBM Inc., Chicago, IL, USA).

Results

The patient characteristics and demographic data are shown in Table 1. Ninety-one patients (60.7%) were male with a mean age and BSA of 61.9 years and 1.7 m^2, respectively. The majority of the patients had coronary artery disease (60.0%) and mitral valvular pathology (24.0%). Seven patients (4.7%) had combined coronary artery disease and severe mitral regurgitation.

The interobserver variability presented as the ICC was 0.835, 0.921, 0.860, and 0.703 for the aortic annulus, sinus of Valsalva, STJ, and proximal ascending aorta, respectively.

The absolute and BSA-indexed aortic root dimensions in men and women are presented in Table 2. The absolute aortic root diameters were significantly greater in men at all levels ($P < 0.001$). The disparity between sexes was small when the diameter measurements were adjusted for the BSA at the aortic annulus ($P = 0.076$) and STJ ($P = 0.076$), except for the sinus of Valsalva ($P = 0.010$) and proximal ascending aorta ($P = 0.006$).

Discussion

This study reports the full spectrum of the aortic root dimensions in adult patients undergoing cardiac surgery. The aortic root sizes are presented as absolute and BSA-indexed values in men and women. The dimensions of all levels of the aortic root are significantly greater in men; however, the values are similar for both sexes after adjusting for the BSA.

Table 1: Patient characteristics and demographic data

	n=150
Sex: male	91 (60.7)
Age (year)	61.9±12.6
Weight (kg)	62.9±13.1
Height (cm)	161.2±9.2
BSA (m^2)	1.7±0.2
Underlying disease	
CAD	98 (65.3)
Diabetes mellitus	61 (40.7)
Hypertension	105 (70.0)
Dyslipidemia	75 (50.0)
Chronic kidney disease	26 (17.3)
Cerebrovascular disease	12 (8.0)
Tobacco use	48 (32.0)
Significant valvular heart disease	
MR	47 (31.3)
MS	9 (6.0)
TR	23 (15.3)
PR	5 (3.3)
Diagnosis	
CAD	90 (60.0)
Severe MR	28 (18.7)
Severe MS	8 (5.3)
CAD and severe MR	7 (4.6)
CAD and severe MS	1 (0.7)
ASD	3 (2.0)
Others	13 (8.7)

Data are presented as number (%) or mean±SD. ASD: Atrial septal defect; BSA: body surface area; CAD: coronary artery disease; MR: mitral regurgitation; MS: mitral stenosis; PR: pulmonic regurgitation; TR: tricuspid regurgitation

Table 2: Absolute and BSA-indexed aortic root dimensions

Diameter (mm)	Mean±SD		*P*
	Male (*n*=91)	Female (*n*=59)	
Absolute values			
Annulus	22.3±2.4	20.3±2.2	<0.001*
Sinus of Valsalva	32.6±3.9	29.8±3.6	<0.001*
STJ	26.4±3.3	23.8±2.6	<0.001*
Proximal ascending aorta	29.3±3.1	27.1±3.1	<0.001*
BSA-Indexed values			
Annulus	12.9±1.6	13.5±2.0	0.076
Sinus of Valsalva	18.8±2.6	19.8±2.3	0.010*
STJ	15.2±2.1	15.8±2.5	0.076
Proximal ascending aorta	17.9±2.7	17.0±2.1	0.006*

BSA: Body surface area; STJ: Sinotubular junction

Roman *et al*. investigated the aortic root dimensions using M-mode TTE.[3] They included 135 healthy adults with an average age of 43 years and an average BSA of 1.85 m^2. The absolute diameters of the annulus, sinus of Valsalva, supra-aortic ridge (or STJ), and ascending aorta were 26 ± 3, 34 ± 3, 29 ± 3, and 30 ± 4 mm in men and 23 ± 2, 30 ± 3, 26 ± 3, and 27 ± 4 mm in women, respectively. These mean dimensions of all levels of the aortic root were obviously greater than our values, particularly the aortic annulus dimension, which presented with differences of 3.7 mm in men and 2.7 mm in women. However, after adjusting the aortic root dimensions for the BSA (annulus, sinus of Valsalva, STJ, and ascending aorta in males: 13 ± 1, 17 ± 2, 15 ± 2, and 15 ± 2 mm; females: 13 ± 1, 18 ± 2, 15 ± 2, and 16 ± 2 mm, respectively), the values were comparable to ours at the levels of the annulus and STJ. It is remarkable that the diameters of the sinus of Valsalva and ascending aorta are greater for both sexes in our study population after being adjusted for the BSA. The differences in the diameters of the sinus of Valsalva and ascending aortic were 1.8 and 2.8 mm in men and 1.8 and 1 mm in women, respectively.

A more recent study on the aortic root dimensions was conducted by Vriz *et al*. using two-dimensional TTE.[4] They evaluated the aortic root dimensions in 1,043 healthy Caucasian subjects with an average age of 44.7 years and an average BSA of 1.8 m^2. The absolute diameters of the annulus, sinus of Valsalva, STJ, and proximal ascending aorta were 21.0 ± 2.2, 31.8 ± 3.7, 26.9 ± 3.7, and 29.1 ± 4.3 mm in men (10.9 ± 1.6, 16.5 ± 2.2, 14.0 ± 2.1, and 15.1 ± 2.5 mm after adjusting for BSA) and 18.7 ± 1.6, 28.5 ± 3.0, 24.4 ± 2.9, and 27.4 ± 3.4 mm in women (11.2 ± 1.1, 17.1 ± 2.1, 14.6 ± 1.9, and 16.5 ± 2.1 mm after adjusting for BSA), respectively. The absolute aortic root dimensions are similar but the BSA-indexed values are greater in our study. The differences in the aortic root dimension range from 1.2 to 2.8 mm in men and from 0.5 to 2.7 mm in women; the greatest differences were observed at the proximal ascending aorta (2.8 mm) and the sinus of Valsalva (2.7 mm) in men and women, respectively.

Campen *et al*. also established reference values for the aortic root diameters using two-dimensional TTE in patients aged more than 15 years.[2] The patient populations included were Caucasian participants with a mean age of 45 years for men and 46 years for women, who presented at the cardiology department. The absolute diameters of the annulus, sinus of Valsalva, STJ, and ascending aorta were 21.8 ± 2.1, 33.4 ± 3.8, 28.5 ± 3.7, and 30.0 ± 4.3 mm, respectively, in men and 19.2 ± 1.9, 29.4 ± 3.4, 25.5 ± 3.2, and 27.7 ± 3.9 mm, respectively, in women. The absolute aortic root diameters at all levels were quite similar to those reported in our study. However, Campen *et al*. did not present the BSA-adjusted values of the aortic root diameter. The mean BSA in women was 1.7 m^2, which was comparable to that in our study. On the contrary, the mean BSA in men was 1.9 m^2, which was greater than that noted in our study; therefore, it may be assumed that the aortic root dimensions in their study may be smaller after stratification by body size.

From the findings of the aforementioned studies, it is apparent that, after eliminating the effect of the BSA, the aortic root dimensions of the patients included in our study are remarkably greater than those of healthy individuals. This finding suggested that the BSA has an effect on the aortic root dimensions and should be carefully considered while establishing the diagnosis by referencing the standard normal values. Other possible factors that contributed to the greater aortic root dimensions noted in this study were age and left ventricle (LV) characteristics. Patients included in this study were apparently older than those included in the previously mentioned studies[2-4] Several studies have consistently reported that the aortic root diameters increase with age[2,4,8]; thus, the aortic root dimensions were greater in our study due to the inclusion of older patients. Moreover, since we included patients with apparent cardiac disease, the associated abnormal LV characteristics (i.e., left ventricular hypertrophy, increased LV mass, increased septal and posterior wall thickness, and increased LV dimensions) may lead to increased aortic root diameters, as evidenced in the study by Gardin *et al*.[12]

The aortic root dimensions in the Thai population have been investigated using TTE in the study by Jakrapanichkul *et al*.[6] They included 81 patients presented with cardiovascular risk factors, such as hypertension, diabetes mellitus, and dyslipidemia. The mean diameters of the annulus, sinus of Valsalva, and STJ were 21.9 ± 1.3, 34.5 ± 0.37, and 25.5 ± 3.5 mm in men and 20.6 ± 1.2, 30.7 ± 3.2, and 23.5 ± 2.7 mm in women, respectively. The absolute aortic root dimensions were slightly greater compared to the values recorded in our study, except for the diameter of the sinus of Valsalva in men, which was greater by 1.9 mm. However, the mean BSA in their study was only 1.6 m^2; hence, the BSA-adjusted values would be even greater compared to the standard normal values.

The major limitation in our study was that the aortic root dimensions were not derived from healthy subjects, instead, we selectively included patients with preexisting cardiac disease who required routine TEE examination. As TEE is an invasive examination, it can be unethical to perform TEE in healthy individuals. Although we tried to eliminate factors associated with aortic root dilatation, the results might be conflicting. Our findings can imply either that the aortic root dimensions of patients with the cardiac disease even without aortic root-related pathology or those of patients who had cardiovascular risk factors might be greater or that the Thai populations may have unexpectedly greater aortic root dimensions than the Caucasians. A comprehensive study on the aortic root dimensions in the Thai populations should be conducted in healthy subjects using other noninvasive modalities, with a special focus on the body size. Another limitation of our study was that we compared the aortic root dimensions derived from TEE with TTE-based values because there was no previous TEE-based study on the aortic root dimensions, although Kabirdas *et al*. had concluded that TTE is an accurate method for the measurement of the diameter of the sinus of Valsalva, STJ, and proximal ascending aorta compared to TEE.[13]

Conclusion

This study reported the aortic root dimensions obtained by TEE in patients with cardiac disease who required cardiac surgery. The absolute aortic root diameters appear to be similar or smaller compared with standard reference values. However, the BSA-indexed diameters are considerably greater at all levels of the aortic root. Therefore, body size should be considered when comparing the aortic root dimensions of Thai populations with standard reference values.

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Conflicts of interest

There are no conflicts of interest.

References

1. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE, *et al*. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease. J Am Coll Cardiol 2010;55:e27-129.
2. Campens L, Demulier L, De Groote K, Vandekerckhove K, De Wolf D, Roman MJ, *et al*. Reference values for echocardiographic assessment of the diameter of the aortic root and ascending aorta spanning all age categories. Am J Cardiol 2014;114:914-20.
3. Roman MJ, Devereux RB, Kramer-Fox R, O'Loughlin J. Two-dimensional echocardiographic aortic root dimensions in normal children and adults. Am J Cardiol 1989;64:507-12.
4. Vriz O, Aboyans V, D'Andrea A, Ferrara F, Acri E, Limongelli G, *et al*. Normal values of aortic root dimensions in healthy adults. Am J Cardiol 2014;114:921-7.
5. Vriz O, Driussi C, Bettio M, Ferrara F, D'Andrea A, Bossone E. Aortic root dimensions and stiffness in healthy subjects. Am J Cardiol 2013;112:1224-9.
6. Jakrapanichakul D, Chirakarnjanakorn S. Comparison of aortic diameter in normal subjects and patients with systemic hypertension. J Med Assoc Thai 2011;94:51.
7. Walther T, Dewey T, Borger MA, Kempfert J, Linke A, Becht R, *et al*. Transapical aortic valve implantation: Step by step. Ann Thorac Surg 2009;87:276-83.
8. Devereux RB, de Simone G, Arnett DK, Best LG, Boerwinkle E, Howard BV, *et al*. Normal limits in relation to age, body size and gender of two-dimensional echocardiographic aortic root dimensions in persons ≥15 years of age. The Am J Cardiol 2012;110:1189-94.
9. Son MK, Chang SA, Kwak JH, Lim HJ, Park SJ, Choi JO, *et al*. Comparative measurement of aortic root by transthoracic echocardiography in normal Korean population based on two different guidelines. Cardiovasc Ultrasound 2013;11:28.

10. Du Bois D. A formula to estimate the approximate surface area if height and weight be known. Nutrition 1989;5:303-13.
11. Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, *et al*. Recommendations for cardiac chamber quantification by echocardiography in adults: An update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Eur Heart J Cardiovasc Imaging 2015;16:233-71.
12. Gardin JM, Arnold AM, Polak J, Jackson S, Smith V, Gottdiener J. Usefulness of aortic root dimension in persons ≥65 years of age in predicting heart failure, stroke, cardiovascular mortality, all-cause mortality and acute myocardial infarction (from the Cardiovascular Health Study). Am J Cardiol 2006;97:270-5.
13. Kabirdas D, Scridon C, Brenes JC, Hernandez AV, Novaro GM, Asher CR. Accuracy of transthoracic echocardiography for the measurement of the ascending aorta: Comparison with transesophageal echocardiography. Clin Cardiol 2010;33:502-7.